Bulletin No. 25.—W. B. No. 191.

U. S. DEPARTMENT OF AGRICULTURE,

WEATHER BUREAU.

WEATHER FORECASTING:

SOME FACTS HISTORICAL, PRACTICAL, AND THEORETICAL.

BY

WILLIS L. MOORE,
CHIEF U. S. WEATHER BUREAU.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Weather Bureau,
Washington, D. C., January 30, 1899.

Hon. James Wilson,
Secretary of Agriculture, Washington, D. C.

Sir: I have the honor to recommend that the inclosed article on weather forecasting, which I contributed for the May, 1898, number of The Forum, be reprinted as a bulletin of the Weather Bureau. The article in question is written in popular style, and contains information as to the movements and progression of storms, the different kinds of storms, how forecasts are made, etc., and in addition, a brief history of the early researches in meteorology and of the organization of the Weather Bureau.

Very respectfully,

Willis L. Moore,
Chief U. S. Weather Bureau.

Approved:
James Wilson,
Secretary.

SOME FACTS ABOUT WEATHER FORECASTING.[1]

HISTORICAL, PRACTICAL, AND THEORETICAL.

To those who are familiar with the application of meteorological science to weather forecasting, and with the material benefits accruing to the commerce and industry of the United States from timely warnings of marine storms, frosts, and cold waves, it will be interesting to note that, at the time of the founding of the first of the Thirteen Colonies, at Jamestown, Va., in 1607, practically nothing was known of the properties of the air or of methods for measuring its phenomena. To-day, at about two hundred stations in the United States, electrically-recording automatic meteorological instruments measure and transcribe for each moment of time the temperature, the air pressure, the velocity and direction of the wind, the beginning and ending of rainfall, the amount of precipitation, and the sunshine or cloud.

That we live in an age of great intellectual acumen, and that he is indeed a wise prophet who can outline, even dimly, the possibilities of the next century, is effectively shown by the development of meteorological science within the recollection of the present generation; although one must admit that in the making of weather forecasts—valuable as these in general are—we have not advanced much beyond the empirical stage. Nor have we any prospect that we shall ever attain the accuracy acquired by the astronomers in predicting the date of an eclipse or the occurrence of celestial events.

It was not until 1643, twenty-three years after the landing of the Pilgrims on Plymouth Rock, that Torricelli discovered the principle of the barometer, and rendered it possible to measure the weight of the superincumbent air at any spot where the wonderful, yet simple, little instrument might be placed. Torricelli's great teacher, Galileo, died without knowing why nature, under certain conditions, abhors a vacuum; but he had discovered the principle of the thermometer. The data from the readings of these two instruments form the foundation of all meteorological science. Their inventors as little appreciated the value of their discoveries as they dreamed of the great Western Empire which should first use their instruments to measure the inception and development of storms.

As early as 1738 Dr. John Lining, of Charleston, S. C., kept a record of the daily temperature in this country. The accurate thermometers

[1] Reprinted from The Forum, May, 1898, by permission.

of Fahrenheit had then been in use but a few years; and, compared with the fine instruments now used for measuring temperature, the error due to imperfect mechanical construction was probably considerable. About one hundred years after the invention of the barometer, viz, in 1747, Benjamin Franklin, patriot, statesman, diplomat, and scientist, divined that certain storms had a rotary motion and that they progressed in a northeasterly direction. It was prophetic that these ideas should have come to him long before anyone had ever seen charts showing observations simultaneously taken at many stations. But, although his ideas in this respect were more important than his act of drawing the lightning from the clouds and identifying it with the electricity of the laboratory, yet his contemporaries thought little of his philosophy of storms and it was soon forgotten. It will be interesting to learn how he reached his conclusion as to the cyclonic or eddy-like structure of storms.

Franklin had arranged with a coworker at Boston to take observations of a lunar eclipse at the same time that he himself was taking readings of it at Philadelphia. Early on the evening of the eclipse an unusually severe northeast wind and rain storm set in at Philadelphia, and Franklin was unable to secure any observations. He reasoned that, as the wind blew fiercely from the northeast, the storm was of course coming from that direction, and that Boston must have experienced its ravages before Philadelphia. Reports indicated that the storm was widespread. What was the surprise of Franklin when, after the slow passage of the mail by coach, he heard from his friend in Boston that the night of the eclipse had been clear and favorable for observations, but that a terrific northeast wind and rain storm began early the following morning. He then sent out inquiries to surrounding stage stations and found that at all places southwest of Philadelphia the storm had begun earlier, and that the greater the distance the earlier the beginning, as compared with its advent in Philadelphia. Northeast of Philadelphia the time of the beginning of the storm had been later than at that city, the storm not reaching Boston until twelve hours after its commencement at Philadelphia.

In considering these facts a line of inductive reasoning brought Franklin to the conclusion that the wind always blows toward the center of the storm; that the northeast hurricane which Boston and Philadelphia had experienced was caused by the suction exercised by an advancing storm-eddy from the southwest, which drew the air rapidly from Boston toward Philadelphia, while the source of the attraction—the center of the storm-eddy—was yet a thousand miles to the southwest of the latter place; that the velocity of the northeast wind increased as the center of the storm-eddy advanced nearer and nearer from the southwest, until the wind reached the conditions of a hurricane; that the wind between Boston and Philadelphia

shifted, and came from the southwest after the center of the storm-eddy had passed over that region; and that the force of the wind gradually decreased as the center of attraction passed farther and farther away to the northeast.

Another man whose name is dear to the heart of every patriotic American conducted in conjunction with his friend, James Madison (afterward Bishop), a series of weather observations, which were begun in 1771 and continued during the stirring times of the Revolution. This was the sage of Monticello, Thomas Jefferson. Madison was near the sea, at the colonial capital, Williamsburg, Va.; Jefferson was at Monticello, 120 miles west. They took simultaneous observations for several years, until the British ransacked Madison's house and carried off his barometer.

Had the telegraph been in existence Jefferson and Madison would doubtless have conceived the idea of a national weather service, as they discovered by comparing observations that barometric and thermometric changes usually occurred at Monticello four or five hours before they did at Williamsburg.

Contrary to the statements which I believe have been made by some historians, the Fourth of July, 1776, was a cool day; for the great author of the Declaration of Independence did not fail to read his thermometer in Philadelphia on that day. An examination of his papers in the State Department, made by an official of the Weather Bureau, proved that he took several readings, viz, 6 a. m., 68°; 9 a. m., 72¼°; 1 p. m., 76°; 9 p. m., 73½°. These early observers did not escape the one unfailing vagary that even at this late period haunts the mind by day and induces feverish dreams by night in nearly every person who has not made a study of meteorological data; for in 1781 Jefferson said:

> A change in climate is taking place very sensibly. Both heats and colds are becoming much more moderate within the memory of even the middle-aged. Snows are less frequent and less deep. They do not often lie below the mountain more than one, two, or three days, and very rarely a week. The snows are remembered to have been formerly frequent, deep, and of long continuance. The elderly inform me that the earth used to be covered with snow about three months in every year.

But Jefferson and his neighbors were mistaken. Never during the period of authentic history has the snow covered the ground in Virginia for periods averaging three months per year for three years in succession. The old inhabitants of Jefferson's time were like those of to-day—they remembered only the abnormalities of the climate of twenty-five or fifty years before, and in comparing the unusual conditions of long ago with the average of the present they were deceived. I have known intelligent and truthful men publicly to declare that they *knew, from personal recollection*, that the climate of

their particular places of residence had changed since they were boys—that they had reliable landmarks to show that the streams were drying up, that the precipitation was growing less, and that the winters were becoming milder—notwithstanding the fact that carefully taken observations of temperature and rainfall for each day for the previous hundred years showed no alteration of climate at such places. Of course, wide variations, sometimes extending over periods of several years, had occurred; but a deficit at one time was made up by an excess at another. To be sure, changes must have taken place during geologic periods; but these have been so slow that it is doubtful whether man in his civilized state has occupied the earth long enough to discover an appreciable quantity. Quite accurate records of the opening of navigation in the rivers of Europe and of the time of vintages for five hundred years show no change in the average data of the first ten years as compared with the average of the last ten; and the date palm, the vine, and the fig tree flourish as luxuriantly to-day in Palestine as they did in the days of Moses. Dried plants have been taken from the mummy cases of the Pharaohs exactly similar to those now growing in the soil once trod by those ancient monarchs.

The matter of change of climate is very important to our subarid West, to the States whose normal rainfall is just enough to produce a profitable crop. Some years ago, when the tide of immigration was strong, there were several years of rather more than average rainfall in regions that theretofore had had little rainfall for profitable agriculture. These two conditions were accidentally coincident; but the fact probably gave rise to the theory that civilization brings an increase in precipitation. It was thought that the breaking of the virgin soil, making it more permeable, and thereby conserving the scant deposit of moisture; the planting of trees and the propagation of vegetation, by restricting the run off and by drawing up the moisture from below the surface of the ground through roots; the enormous quantities of acqueous vapor injected into the air by the combustion incident to a teeming population—had all combined to increase the rainfall and to render the subarid plains more responsive to the efforts of the husbandman. No one with even a spark of that fellow feeling which "makes us wondrous kind" can fail to regret that this theory is not founded upon fact. But a moment's thought will indicate to the physicist that the volume of superincumbent air is so great, and its capacity for moisture so enormous, that the additional vapor of water evaporated as above described, great though it be, is ineffectual to change appreciably the amount of rainfall which nature beforehand had ordained should be precipitated.

The size of continental areas, the topography of the land surface, the proximity of large bodies of water, and the direction of the pre-

vailing winds, are all factors in determining the precipitation of a region; and it is probable that the feeble efforts of man will never be able materially to modify the result.

If the Rocky Mountains were eroded down to the height of the Appalachian chain, the vapor-laden winds from the Pacific would blow inland, and probably cause copious rainfall as far east as Colorado, western Kansas, and western Nebraska. But these are changes which can be accomplished only in long geologic periods.

During the first half of the nineteenth century—nearly a hundred years after Franklin's northeast rain storm—Redfield, Espy, Loomis, Henry, and other American scientists laboriously gathered by mail the data of storms after their passage, and demonstrated their principal motions to be much as Franklin had supposed. In 1855 Prof. Joseph Henry, Secretary of the Smithsonian Institution, constructed a daily weather map from observations collected by telegraph and nearly simultaneous. He did not publish his forecasts, but used his large wall map for the purpose of demonstrating the feasibility of organizing a Government weather service. If there were no other achievements to the credit of the grand institution founded in this country through the benevolence of the English philanthropist, James Smithson—who, by the way, never gazed upon our fair land—the work of the Smithsonian Institution in connection with practical meteorology should always accord it a warm place in the hearts of those who believe that the crowning achievements of science consist in giving to the world knowledge which results in the saving of human life, the amelioration of the sufferings of humanity, and the acceleration of the wheels of commerce and industry.

Although American scientists were the pioneers in discovering the progressive character of storms, and in demonstrating the practicability of weather services, the United States was only the fourth country to give legal autonomy to a weather service. Holland established a weather service, with telegraph reports and forecasts, in 1860; England followed, with a smaller service, in 1861; and France, in 1863. But none of these countries has an area, from which observations can be collected, great enough to give such a synoptic picture of storms as is necessary in the making of useful forecasts. It would require an international service, embracing all the countries of Europe, to equal ours in extent of the area covered and in the accuracy of its forecasts.

The vast region now included in the scope of the Weather Bureau system of observations embraces Canada and the Gulf of Mexico; the whole having an area extending two thousand miles north and south, three thousand miles east and west, and so fortunately located in the interest of the meteorologist as to include an important arc on the circumpolar thoroughfare of storms of the Northern Hemisphere.

Simultaneous observations, collected twice daily by telegraph from about two hundred stations, distributed throughout this great area, render it possible at several central offices, where all the reports are received, to present to the trained eye of the forecaster a wonderful panoramic picture of atmospheric conditions. Every twelve hours the kaleidoscope changes, and a new graphic picture of actual changes is shown. The movements of the storm centers and cold-wave areas are noted, and estimates made as to their probable course during the next twenty-four hours. Where else can the meteorologist find such an opportunity to study storms and atmospheric changes? The widely differing elevation, topography, temperature, humidity, and aridity of the broad region under observation offer unequaled conditions for the study of the mechanical phases of storm development and progression—so far as such can be profitably studied with observations taken only at the bottom of the ocean of air surrounding the earth. Our storms and cold waves can be studied during their inception at an average altitude of five thousand feet above sea level, under conditions of extreme aridity; they can be observed later, as they come down almost to sea level in the Mississippi Valley and reach a more humid atmosphere one thousand miles from the place of their birth; and, finally, they can be seen as they reach the extremely humid air of the Atlantic Ocean, fifteen hundred miles farther east.

The great winter storms which originate south of the Japanese Islands and cross the Pacific Ocean come under our vision as they successively surmount the formidable Rocky Mountains with but little diminution of energy, sweep across the continent with increasing force and heavy precipitation and within three days pass beyond our meteorological horizon at the Atlantic seaboard, to be heard from occasionally three days later as boreal ravagers of northern Europe.

The great anticyclones, or high-pressure areas, which constitute the American cold waves, drift into our territory from the Canadian northwest provinces and are studied under rapidly changing conditions during 3,000 miles of their course. The high-pressure eddy, with all the convectional principles of the cyclone reversed, may be said not to depend upon the land of its birth for the cold it brings; for a strong vortical and anticyclonic motion at the center is continually bringing down the cold air from above. In other words, our cold waves are not, as was once supposed, masses of heavy air chilled by flowing over the snow and ice fields of the Arctic Ocean and transported to our central valleys with such rapidity of translation as to retain much of their original frigidity.

In 1870 and for some years thereafter our forecasts and storm warnings were looked upon by the press and the people more as experiments than as serious statements. The newspapers especially were prone to comment facetiously on the forecasts, and many were

clamorous for the abolition of the service during the first years of its existence. There was some ground for the criticisms. We knew nearly as much about the mechanics of storms at that time as we do to-day; but we had not—by a daily watching of the inception, the development, and the progression of storms—trained a corps of expert forecasters such as now form a part of the staff of the Chief of the Weather Bureau, and from which he himself was graduated. After a time mariners began to note that danger signals were, in the great majority of cases, followed by heavy winds, and they reasoned that it were better to take precaution against forecast storms that never came than to be unprepared for those which did come.

It is a fact that many times, by the operation of forces not indicated by the surface readings, the barometer at the center of a storm begins to rise and the velocity of the whirling mass to decrease. In such cases the storm signals placed in advance of the storm center would fail to give the proper information. Again, the storm center may suddenly acquire a force not anticipated, or it may pursue a track considerably divergent from the normal for the location and season. In this case, also, the forecasts may warn some cities that fail to receive the effects of the storm. The staff of the Weather Bureau, which includes many able meteorologists, has not failed to make a study of the peculiarities of the several types of storms occurring in different localities during the various seasons of the year, their line of travel, and the force that they may be expected to attain. The comparative merits of those who by natural ability were best fitted correctly and quickly to correlate in their minds the conditions shown on a meteorological chart and to make accurate deductions therefrom as to the development, movement, and force of storms have been tested by competitive examinations. This line of study and competition has resulted in improved forecasts, so that mariners now universally heed the storm warnings, horticulturists and truck gardeners make ample provision against frost, and shippers of perishable produce give full credence to the cold-wave predictions. Of the many West Indian hurricanes which have swept our Atlantic seaboard from Florida to Maine during recent years not one has reached a single seaport without danger warnings having been sent well in advance of the storm, and no unnecessary warning has been issued. The result is that no disaster of consequence has occurred. Large owners of marine property estimate that one of these severe storms traversing our Atlantic coast in the absence of danger signals would leave not less than $3,000,000 worth of wreckage. On two occasions a census was taken immediately after the passage of severe hurricanes to determine the value of property held in port by the danger warnings sent out in advance of the storms. In one case, the figure was placed at $34,000,000; in the other, at

$38,000,000. Of course this does not represent the value of property saved. It simply shows the value of property placed in positions of safety as a result of the danger signals and warning messages sent to masters. On January 1, 1898, an extensive cold wave swept from the Rocky Mountains eastward to the seaboard. Estimates secured from shippers in one hundred principal cities indicated that property valued at $3,400,000 was saved as a direct result of the predictions sent out.

There is hardly a daily paper that does not publish weather forecasts in a prominent place, and there is scarcely a reader who fails to note the predictions. The utility of these forecasts to the agriculture, the commerce, and the industry of the country is so great that it may be interesting to note more in detail the methods by which observations are collected, forecasts made, and meteorologic information disseminated.

Our Weather Bureau maintains about two hundred regular meteorological stations, each in charge of a trained observer, advantageouly located geographically for the taking of observations. The transmission of reports is accomplished with remarkable rapidity by means of an effective arrangement of telegraphic circuits. Observations from all parts of the United States and Canada, from the Atlantic to the Pacific, are collected at Washington within thirty minutes after the observers have read the station instruments and filed their observations. Synoptic charts are prepared in the central offices at Washington and Toronto, and at many of the large stations at which reports are received; and by 9 o'clock (seventy-fifth meridian time) the charts are complete. The chart of greatest value to the forecaster contains for each station the temperature, barometric pressure, wind direction and velocity, weather conditions—whether raining, snowing, cloudy, partly cloudy, or clear—and the amount of precipitation, if any. Lines, called "isobars," are drawn for each one-tenth of an inch of barometric pressure, bounding the areas over which the air is respectively lightest and heaviest. These areas are called "highs" and "lows"; but they are only relative terms, as on one map the highest pressure may be over two inches in excess of the lowest, while on the map of another day the difference may be less than one inch.

Several other charts are prepared in the forecast room of the Central Office at Washington, as follows: Temperature-change map, showing the maximum and minimum temperature at each station, with changes from the day before and changes from the normal; barometer-change map, showing twelve and twenty-four hour changes and changes from the normal; cloud map, indicating the character, nomenclature, quantity, and movement of clouds; and a map showing wet-bulb and dry-bulb temperatures, with differences between the two.

If the student of the weather maps will pay close attention to them each day, he will find that the highs and lows move across the country in almost regular succession. If the high be a decided one, it will cover a territory one or two thousand miles in width, the weather within its influence will be cold and clear, and the winds will have a general tendency spirally outward from the center in a direction corresponding to the movement of the hands of a watch. The low is the opposite of the high in almost all its characteristics. It is usually attended by clouds, rain or snow, and high winds. The winds within the influence of the low blow spirally inward in a direction contrary to those under the influence of the high. The lower the barometer and the steeper the gradient, the more rapid is the whirl. These are some of the characteristics of lows. Those of like class take nearly the same course, and produce about the same results; but they do not always move with the same rapidity. No exact rule in regard to them can be laid down. Empirical reasoning, and intimate association with the charts, day after day and year after year, in the main equip the successful forecaster for his important functions.

Just as the eddies in a river go whirling down stream, so are cold-wave eddies (highs) and rain-storm eddies (lows) carried eastward by the general movement of the upper atmosphere in the latitudes of the United States. It is important that the fundamental principles of these eddies be understood, since the weather changes experienced from day to day depend almost wholly upon the development and drift of these high-pressure and low-pressure eddies, or, as they are better known, highs and lows. The two eddies are easily distinguishable the one from the other; for, while traveling eastward in the same general direction, they rotate in opposite directions. The high-pressure eddy always follows in the track of the low-pressure eddy. In the high-pressure eddy—in which the air is cold and clear, and in which the degree of cold is nearly proportional to the rise of the barometer—the air is drawn downward near the center of the eddy, and forced outward in all directions from the center along the surface of the earth. This eddy at times is two thousand miles in diameter. In the low-pressure eddy—in which the air is warm, humid, and often rainy or snowy—the surface air is drawn inward from all directions toward the center. Thus, the alternate passage of highs and lows controls our weather conditions.

About six-sevenths of our low-pressure eddies move from the Rocky Mountains eastward. They vary from the gentle whirls to storms of considerable intensity. Their average diameter is about one thousand miles. The West Indian hurricane, which comes up from the Tropics and skirts along our Atlantic shore-line, has a diameter of rotation less than one-half that of the usual low-pressure eddy; but its velocity

of rotation is much greater. Many of these hurricanes have a diameter of only three or four hundred miles; but their velocity of rotation is very often one hundred miles per hour, although their rate of translation, as they move northeast along our coast, is seldom greater than thirty miles per hour.

Twenty-five years ago mariners on our Great Lakes and seaboard depended on their own weather lore to warn them of coming storms. Then, although the number of craft plying on our waters was much less than now, every severe storm that swept the Lakes or Atlantic coast left destruction and death in its wake, and for days afterward the dead were cast up by the receding waves, and the shores were lined with wreckage. Happily this need not now be the case, for the Weather Bureau of the Department of Agriculture is ever watching the changes of atmospheric conditions and giving the mariner warning of coming storms. Each observer telegraphs instantly to the Central Office whenever the instruments at his station show unusual agitation. By this means the inception of many storms is detected when the regular morning and evening reports fail to give notice of their origin.

Some idea of the vast interests floating in Atlantic ports may be had when it is stated that 5,628 transatlantic steamers, with an aggregate of 10,076,148 tons, and 5,842 sailing craft, aggregating 2,105,688 tons, enter and leave ports on the Atlantic seaboard during a single year. The value of their cargoes is more than a billion and a half of dollars. Our coastwise traffic also is enormous. In one year more than 17,000 sailing vessels and 4,000 steamers enter and leave ports between Maine and Florida. Their cargoes are estimated to be worth $7,000,000. From these facts one can roughly measure the value of the marine property which the Department of Agriculture, through the work of the Weather Bureau, aims to protect by giving warning of approaching storms.

It is the dream of the meteorologist that some day he will be able accurately to forecast the weather weeks and months in advance. But so far this much-to-be-desired object can be realized only in a dream. What a wonderful conservation of human energy would result were it possible to tell the farmer when the great corn and wheat belts would have abundant rain during the next growing season, or when droughts would parch the vegetation, or truthfully to inform the planter of the South that the approaching season would be favorable or unfavorable to the production of cotton! Effort would be withheld in one part of the country and prodigious energy exerted in another.

When our extensive system of daily observation has been continued for another generation a Kepler or a Newton may discover such fundamental principles underlying weather changes as will

make it possible to foretell the character of coming seasons. If this discovery be ever made it will doubtless be accomplished as the result of a comprehensive study of meteorological data of long periods covering some great area like the United States. At any rate we are certainly now laying the foundation of a great system which will adorn the civilization of future centuries.

At the present time I know of no scientific man who essays to make long-range weather predictions, and I would especially caution the public against the imposture of charlatans and astrologists, who simply prey upon the credulity of the people. As storms of more or less intensity pass over large portions of our country every few days during the greater part of the year, and as it is seldom that the weather report does not show one or more storms as operating somewhere within our broad domain, it is easy to forecast thunderstorms about a certain time in July or a cold wave and snow about a certain period in January and stand a fair chance to become accidentally famous as a prophet. You may select any three equidistant dates in January and forecast high wind, snow, and cold for New York city and stand a fair chance of having the fraudulent forecast verified in two out of the three cases; provided that you claim a storm coming the day before or after one of your dates to be the storm which you expected.

I believe it is impossible for any one to-day to make a forecast, based fairly upon any principles of physics or upon any empiric rule in meteorology, for a greater period than one or two days in winter or for more than two or three days in summer; and there are times in winter when the movements of air conditions are so rapid that it is extremely difficult to forecast even for the space of one day. The Weather Bureau takes the public into its confidence in this matter and does not claim to be able to do more than it is possible to accomplish.

Having reached the highest degree of accuracy possible with our present instrumental readings, it becomes necessary to invade new realms if we desire to improve the character of the forecast and to make it of greater utility. I have long realized this, and several years ago determined systematically to attack the problem of upper-air exploration with the hope of being able ultimately to construct a daily synoptic chart from simultaneous readings taken in free air at an altitude of not less than 1 mile above the surface of the earth. During the past ten years there has been much discussion as to the best means of improving weather forecasts by readings secured at high levels. Many stations have been established on mountain peaks; but, unfortunately, the observations from these places have been of little use to us in making the daily forecast.

It is my opinion that plans previously advocated by many for iso-

lated investigations in the upper air by means of free and uncontrollable balloons, by observers in balloons, or by independent kite stations striving for very great flights, were of little value in getting the information absolutely necessary to the more accurate determination of the mechanics of storms. It is my belief that the only feasible plan is that of simultaneous observations at such uniformly high level as can be attained with kites at many stations. With only a moderate surface wind our improved kites will now ascend easily to the height of one mile or over, and will carry up an automatic instrument, mainly of aluminum, weighing about two pounds, which records temperature, pressure, humidity, and wind velocity.

The Weather Bureau intends to establish tentatively fifteen or twenty stations between the Alleghanies and the Rocky Mountains during the present spring, and to make special effort to secure observations at the same hour at a high level from all the stations, so that the meteorological conditions at that altitude may be compared with those prevailing at the surface of the earth. If we are successful in attaining the desired altitude at enough of our stations each day to give the data from which a synoptic chart can be constructed, we shall then be able to map out not only the vertical gradients of temperature, humidity, pressure, and wind velocity, but also the horizontal distribution of these forces at two levels—one at the earth's surface and the other at the height of one mile. It may be that after this work is done only negative knowledge will be acquired; but, even then, the work will not have been in vain. It will be an instructive study to note the development and progression of storms and cold waves at this high level. At that altitude the diurnal variations cease; there is but little change between the heat of midday and that of midnight; so that storm conditions may be measured without the confusing effects due to immediate terrestrial radiation.

The temperature readings already secured by our use of kites show that in the summer season we live in an extremely thin stratum of warm air; that on the hottest day an ascent of only 500 to 1,000 feet in free air would place a person in a comfortably cool atmosphere; that the temperature at an altitude of 3,000 feet is slightly higher at midnight than at midday; and that changes of wind and of temperature begin at high levels sooner than on the surface of the earth.

It is a problem for the engineer of the twentieth century how to utilize this information so as to give relief during the protracted hot spells of summer to the dense population of great cities, and so that one need not travel to the seashore in order to reach a temperature that is conducive to health and comfort.

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